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METALLURGICAL PROCESSES IN MULTI-COMPONENT RARE EARTH-TRANSITION METAL PERMANENT MAGNET ALLOYS

FINAL REPORT

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A metallurgical model has been employed to achieve record values of energy product $Sm_2(Co,Fe)_{17}$ type permanent magnets modified by Cu and Zr, $(BH)_{max}$=33-34 MGOe. Record values were also obtained in fully temperature compensated versions modified by Gd, with $(BH)_{max}$=18-19 MGOe. Fourteen references. Eight publications appended to report.

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METALLURGICAL PROCESSES IN MULTI-COMPONENT RARE EARTH-TRANSITION METAL PERMANENT MAGNET ALLOYS

FINAL REPORT

The primary objective of this research has been to improve and extend the technology of 2:17 type permanent magnets. The research has proceeded by employing a model for the complex metallurgical behavior of these alloys. This model was conceived by the principal investigator during ARO Proposal No. 17973[1-2]. It was defined and reported during 21026-MS[3-5] and has been continually refined during the present contract 24674-MS[6-8]. A description of the most recent version of the model is given in reference 9.

During the three year period of this research, we have succeeded in establishing a record value $(BH)_{max}$=34 MGOe for energy product in uncompensated $Sm(Co_uFe_vCu_xZr_y)_z$ magnets[10,11]. This was achieved by increasing the Fe content to v=0.31-0.33 (28-30 at.%) while developing heat treatments to maintain the coercivity at high levels. While 34 MGOe represents about a 6% increase over the previously announced laboratory record, we believe that the technology we have developed should routinely yield 31-32 MGOe magnets in commercial production - a 15% increase over the best 2:17 magnets presently produced. Utilizing similar compositions, slightly modified heat treatments, and Gd substitution for slightly less than half of the Sm, we achieved $(BH)_{max}$=18-19 MGOe in fully temperature compensated magnets. This also represents a 15% increase over the best commercially available magnets of this type[10,12]. Finally, we have been able to raise the remanence, B_r, of uncompensated 2:17 magnets by the partial substitution of Sm by light rare earths (Ce, Pr, and Nd singly and in combination)[13,14]. We also obtained excellent loop shapes from the latter substitutions, apparently by the development of more uniform, but high energy pinning sites.

From our present understanding of the metallurgy of 2:17 alloys, it appears we have about reached the practical limit for increasing the Fe content as a means for raising B_r and $(BH)_{max}$. Further improvement is possible, however, by optimizing the solutionizing and aging heat treatments to obtain better second quadrant loop shapes. We can prepare magnets with B_r=12.2 Kg and ${}_MH_c$>18 kOe, but due to the poor loop shape, H_k and ${}_BH_c$ are low. With proper heat treatment, such magnets should be capable of 36-37 MGOe energy products.

ARO has supported our work on 2:17-type permanent magnets for nine years. During that period, we have developed a fundamental understanding of the metallurgical behavior of the magnet alloys. We have utilized that knowledge to achieve world record energy products for magnets of this type in both uncompensated and fully temperature compensated modifications. We believe we now possess a unique and valuable body of knowledge concerning these high performance magnet materials. We believe the magnet compositions and processing procedures we have developed could be utilized in commercial production to yield 2:17 type permanent magnets substantially better than those presently available.

Scientific personnel supported by this project include Alden E. Ray, Karl J. Strnat, Herbert F. Mildrum, Shiqiang Liu, J. Douglas Wolf, Meng Li, and Christopher Ivary. Shiqiang Liu was awarded the Ph.D. degree in Materials Engineering in December 1989. Meng Li was awarded the M.S. degree in Materials Engineering in April 1990 and Christopher Ivary will be awarded the M.S. degree in Materials Engineering in July 1990.

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LIST OF PUBLICATIONS DURING THIS CONTRACT

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